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THE

AMERICAN NATURALIST.

Vol. VII.—FEBRUARY, 1873.—No. 2.

# COLORS OF VEGETATION.*

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THE coloration of plants is due to the presence in the cells of minute globules, which are usually green in the herbaceous parts, the leaves, sepals, etc., and of various hues in the flowers and fruits.

The normal color of foliage is green, but it may be of almost every conceivable shade and degree of intensity. It may be of a yellowish-green as in the parsnip, or of a blue-green as in the sweet pea. It may be pale and shining as in the orchis, or dark and shining as in the laurel. It may be intense and vivid as in the young leaves of the horse-chestnut, or of a neutral Portage sandstone color as in the Cassandra or leather leaf.

The causes of these differences are partly chemical and partly physical: the chemical causes producing the different shades of color, the physical the differences in brightness and intensity.

First, as to the chemical differences. The French chemist Frémy finds that chlorophyl or leaf green is composed of two distinct substances: the one of a bright blue color which he calls *phyllocyanin;* the one of a yellow color known as *phylloxanthin.* The unequal proportions of these two ingredients which are simply mixed in the leaf cells would account for the absolute differences in color. Thus in the bluish-green leaves of the pea

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*Read before the Cornell University Natural History Society.

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family the blue substance should be found to predominate, and in the yellowish-green leaves of the hickories the yellow substance should be in the ascendant. Indeed it has been found that, in the outer leaves of the cabbage, the phyllocyanin or blue substance exists in much greater proportion than in the inner leaves which have been deprived of sunlight.

Now as to the physical causes producing differences of intensity. In the dark shining leaves such as those of the laurel, prince's pine, partridge berry, etc., the depth of color is due to the closeness with which the cells are packed together. Each cell contains a globule of chlorophyl, and it is evident that, other things being equal, the smaller the cells and the more compact their arrangement, the darker will be the color of the leaf.

And as to the differences in vividness of color. In the young leaves of the horse-chestnut, the cuticle is very thin and the cellular substance of the leaf is very transparent; hence the green of the globules of chlorophyl shows brightly through. On the contrary, in the Cassandra or leather leaf, the cellular tissue is of a thick husk-like texture and the leaves are of necessity dull colored. The blue coloring substance in leaves is much less stable than the yellow. It rapidly decomposes or is transformed in the absence of sunlight. You have all noticed what a yellow hue the foliage of trees wears in wet and cloudy springs, and even in summer, a week or two of sunless weather will often make a perceptible difference in the color of the woods. Always the lower and inmost leaves of a tree are paler than the rest and of a yellowish hue, like the complexion of boys "brought up in the house." Cold weather bleaches chlorophyl and vegetable coloring matters generally. The further north we go the more liable do we find plants to albinism or loss of color. Flowers of Arctic or mountainous regions are always paler and more delicate in hue than those of warm countries and they are far more subject to white varieties. Linnæus says that "there is not a single blue or red flower in Lapland that has not its white varieties." The yellow coloring matter is much less easily affected by absence of light and other causes and yellow flowers rarely exhibit any striking variations in hue. Many plants are entirely destitute of chlorophyl. These are parasites, and as they depend for their nutrition on the sap already elaborated by the supporting plant they have no need of chlorophyl. The cells may be filled with orange-purple or tawny coloring substances or they may be empty, leaving a white plant, like the Monotropa and mushroom. Lichens and fungi growing on living or decaying organisms have also no need of chlorophyl; hence in the economy of nature they are unprovided with it. They often exhibit bright tints due to the presence of various coloring matters whose character is not well understood. Recent experimenters have succeeded in isolating some forty different coloring substances in a species of mushroom. Some fungi are luminous like the glow-worm. I do not know the theory of this. That peculiar luminosity of rotten wood, often supposed to be "phosphorescence" and known by woodsmen as "fox fire," is due to the presence of a species of fungus.

Much has been written about autumn coloration, but the subject has been treated from an æsthetic rather than from a scientific standpoint. We are more interested in "the rosy cheek than we are to know what particular diet the maiden fed on." However, in a general way, we say that the bright colors of leaves in the fall are caused by the oxidation of the chlorophyl. This is really a process of ripening. A brilliant autumn leaf is not dead but mature. "Flowers are but colored leaves, fruits are but ripe ones. The edible part of most fruits is the parenchyma or fleshy tissue of the leaf of which they are composed." The ripening of a maple leaf and a red astrachan apple is precisely the same process. In both cases it is an absorption of oxygen and a change of the blue substance of the chlorophyl to red. The yellow substance is not easily acted upon, hence the prevailing color of autumn foliage is scarlet, which is a mixture of yellow and red.

M. Châtin has a different theory as to the production of scarlet leaves. He claims that the entire mass of chlorophyl is oxidized first to yellow and then to red, and that red leaves contain yellow chlorophyl in the inner cells which has not yet been oxidized. He thinks that yellow leaves in autumn are those in which the process has been arrested at the yellow stage before they arrive at redness. But the leaves of the oaks become crimson without passing through any intermediate stages of yellow or scarlet. This theory also appears improbable in the case of the hickory, aspen, etc., whose bright yellow autumn foliage shows no tinge of red. Besides such a change as he imagines would be inconsistent with the theory of the compound nature of chlorophyl.

It seems to be pretty well established by the experiments of

M. Cloez and others on the different varieties of hyacinth and bachelor's button (Centaurea cyanus), that oxygenation or acidification changes vegetable blues to red, and that the two colors are chemically identical and chemically distinct from the yellow. In ordinary leaves, we find the blue and yellow substances nearly in equilibrium, but in the colored parts of the flower, one or the other predominates. Thus flowers are naturally divided by their colors into two great classes, according to whether the cyanic or xanthic principle is in the ascendant.

Desvaux, one of the most painstaking of observers, has studied for ten years the gradations of color in the twelve hundred varieties which have been produced of the kidney bean. He divides the colors of flowers into two series.

1st. The cyanic series, those having blue for their type and capable of varying to red or white, but never to yellow.

2d. The xanthic series, those having yellow for their type and capable of varying to orange or white, never to blue. Both series commence in green, which is blue and yellow, and end in white which is the absence of all color.

Thus the tulip was originally yellow. All of its varieties belong to the xanthic series. So with the dahlia and zinnia. There never was a blue tulip, primrose or dahlia. The geraniums, phloxes, verbenas, etc., vary throughout the cyanic series, and a yellow geranium or phlox is unknown.

Different species of the same genus sometimes belong to different series, as is the case with the roses and violets. Rarely different parts of the same flower belong to different series as in the convolvuli and forget-me-nots. Though the rules of color are liable to many exceptions, yet it seems to me that Linnæus' great maxim "Nimium ne crede colori," "Put not your trust in colors," is too absolute. For example, the hue of a single petal of Solanaceæ stamps at once the order.

"The science of Vegetable Chromatology," observes M. Guérin, "is yet in its infancy; and it is impossible to establish any rules to which there are not many exceptions."

All theories yet advanced, however ingenious they may be, are liable to objections of such great weight that none can be admitted as absolutely true. For example, let us take the theory of Macquart, that "color results from the decomposition of carbonic acid and the disengagement of oxygen, and that its intensity is proportional to the amount of luminous fluid—light, which is present." This decomposition can take place only in the presence of sunlight and chlorophyl, but there are many parts of plants in which chlorophyl is entirely wanting and which develop in the absence of light, yet which nevertheless are brightly colored. Roots and tubers are often of brilliant hues, as in the carrot and gold-thread. So also the inner wood of a tree, as in the magnolia and rosewood. These colors are formed in the presence neither of sunlight nor chlorophyl, so there must exist other causes of coloration than that allowed in the theory of Macquart.

Again, although submarine vegetation is usually of a dull green or brown, we find many seaweeds which are brilliantly tinted, although they receive but a very feeble light. Although chemical analysis throws some light on the laws of vegetable chromatology, yet the color of the flowers cannot in general be taken as any index of the medical properties of plants, for we may find the same colors at once in the most poisonous herbs, as fox glove and belladonna, and in the most innocent, as the primroses and violets.

The flowers of many plants are subject to changes in color. The closed gentian, for example, changes from a deep indigo-blue to a reddish-purple. The white Trillium becomes of a delicate rose color just before it withers. The ray flowers of Xeranthemum are straw color when they first expand becoming, at last, of a bright crimson. A more striking example is the *Gladiolus versicolor* which is brown when it opens in the morning, changes to a clear blue in the noonday sunshine and returns to brown again at night to go through the same variations the next day.

Black as a color exists in vegetation only in the roots, seeds and a few fruits. It does not occur in the flowers. All the approaches to it, as in the case of the dark spot on the corolla of the coffee bean, are simply an intense violet. There are no flowers of a pure white. The famous flower painter Redouté, observed long ago that in flowers which appeared white, there is always a faint tinge of rose color, yellow or blue. When a white petal is viewed by transmitted light we see various shades produced by some coloring matter present in the cells in a state of extreme dilution. White frequently with a tinge of pink is the most common color in spring flowers and in flowers of Arctic regions. Red is the hue of summer flowers and of acid fruits; bright red is rarely seen in early spring flowers and in the autumn it also disappears. But in June and July, the flowering time of the roses, laurels and azaleas, it is one of the most abundant colors. Yellow is more properly an autumnal color, and it often characterizes large groups, as the golden rods, sunflowers and buttercups. Blue is a summer color, but it runs throughout the year from the hepaticas of the hue of the March sky above them, to the fringed gentians and asters of the November woods.

Numerically, yellow flowers are far the most abundant: next comes white, then red and blue. Red is very often the hue of the stems of plants especially in late summer and autumn. This is common among the grasses, some of which brighten into a purple mist as intense in color when seen at a little distance, as the most brilliant patches of laurel or meadow beauty.

" In most plants," says Thoreau, "the corolla or calyx is the part which attains the highest color and is the most attractive; in many it is the seed vessel or fruit, in others still it is the very culm itself which is the blooming part."

In conclusion we come to the question, what is the use of the colors of vegetation? In a strictly utilitarian point of view they seem unimportant. There are some plants, chiefly orchids, which require the aid of insects to secure fertilization and which attract them by their bright colors, but these plants are very few and most flowers could accomplish their destined purpose just as well were they clad in the drab of the veriest Quaker.

The flowering time is the nuptial season, the honeymoon of the plant, and it is the nature of flower and beast, of bird and man to " spruce up," to put on his brightest colors at pairing time.

The science of Vegetable Chromatology is one in which much is seen and little is known. We can all see with our own eyes that plants are variously colored: that even Solomon in all his glory was not arrayed like one of our meadow lilies; but when we get beyond our eyes and ask why this is so, we find ourselves at a loss; we cannot answer. We only know that the Lord doeth as pleaseth Him with the flowers in his garden.